MCAT—A Multimedia Cardiac Angiogram Tool

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ABSTRACT

In this article, we present the prototype of the Multimedia Cardiac Angiogram Tool (MCAT). The MCAT provides capabilities for reviewing angiograms recorded at a cardiac catheterization laboratory. A doctor can use MCAT to annotate angiograms with audio, text, and graphics. He/she can selectively package the annotated multimedia angiograms into a document, save it as the record for the visit or use it for case presentations, or send it to another doctor over a network. MCAT streamlines data collection at a cath lab and is intended to improve the efficiency of communication and collaboration between doctors. This paper describes the design, implementation, and future directions of the prototype.

INTRODUCTION

The Multimedia Cardiac Angiogram Tool (MCAT) is one of the research tools of the Electronic Case Folder System (ECF) being developed at Philips Research Laboratories at Palo Alto (PRPA) CA and Briarcliff NY. Together with the ECF system, the MCAT employs state-of-the-art computer technology to improve the efficiency and quality of health care delivery at a cardiac catheterization laboratory (cath lab). To achieve this goal, MCAT streamlines the diagnostic process and allows doctors to communicate more effectively using integrated video, audio, text, and graphics.

Streamlining the data collection and diagnostic process at a cath lab can significantly increase the efficiency and consequently reduce the operating costs while improving the quality of patient care. Currently, data are gathered at a cath lab by different machines and stored on incompatible media. For example, the angiograms are stored on celluloid films, and the physiological data (e.g. blood pressure) are stored on computer disks. After the scattered data are collected for a patient, the doctor must use different machines to review different data. For example, projectors are used to review the films and PCs are used for physiological data. The doctor then dictates the diagnosis to a tape recorder, which is later transcribed by a different person. The current process is tedious and slow; MCAT is designed to improve the process by automatically collecting the data and allowing doctors to view and augment the data on a single system.

Cardiologists at a cath lab believe that the care for cardiac patients can be significantly improved if they can communicate more effectively with the referring cardiologists who routinely take care of the patients. Currently doctors communicate through telephone and send text transcriptions through fax. If a referring cardiologist needs to see angiograms, he/she must either order the celluloid film and wait for its delivery or travel to the cath lab. The process is time consuming and sometimes causes loss and damage of the films. As a result, referring cardiologists usually only read the cath lab reports and have very limited participation in making decisions of patient treatment at the cath lab. Patient care can be improved by immediate participation in treatment planning by the referring cardiologist who best knows the overall health status of the patient. MCAT is designed to facilitate the communication and collaboration between doctors by providing the capability of multimedia annotation, mailing, and presentation.

Case discussions occur frequently among health care professionals. To prepare a case presentation at the present time, a cath lab cardiologist often prints out key frames and augments them with text and other information. It will be more convenient if the angiogram reviewing tool also helps the doctors to compose documents for case presentations. The presentation can be more effective if the document can include cardiac video clips with related dictations since the diagnosis is based on dynamic flow patterns of the contrast medium in the coronary arteries and heart chambers. MCAT provides capabilities for doctors to clip key video frames and sequences from an angiogram, annotate them with dictation, text, and graphics, and

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organize the multimedia components in a single document. The document can then be used by related tools for education, case presentation, and patient records.

Related Projects

PRPA is also involved in a collaborative project on the California Research and Educational Network (CalREN)[1] funded by Pacific Bell. This project is to construct a prototype digital system capable of capture, archive, and review of cardiac video sequences. The prototype of MCAT uses the cardiac angiograms captured by the system developed for the CalREN project.

Similar work to MCAT has been done in the EasyVision^{TM} of Philips Medical Systems [8] and the Cardiac Image Network of Brown University and the Miriam Hospital[2]. However, both systems emphasize review of cardiac images of multiple modalities and does not support multimedia angiogram annotations and document composition for case presentation. Multimedia annotation tools have been developed at University of Miami[3]. However, their tools are designed for the radiology department and therefore do not include video components.

Hardware Setup

Figure 1 depicts an example of the hardware setup in which MCAT operates. The left side of the figure shows a patient under examination in the cath lab of the San Francisco Kaiser Hospital. The digital angiographic data is collected by the Philips Digital Cardiac Imaging system (DCI) and sent to a workstation (WS1). The workstation is expected to be connected to the existing Hospital Information System (HIS) and a RAID (Redundant Array of Inexpensive Disks [7]) storage system. The angiograms are first stored at the RAID system and periodically sent to an archival system. The angiograms can be annotated and viewed on workstations and PCs attached to the network. Sun Sparc stations are used in the prototype.

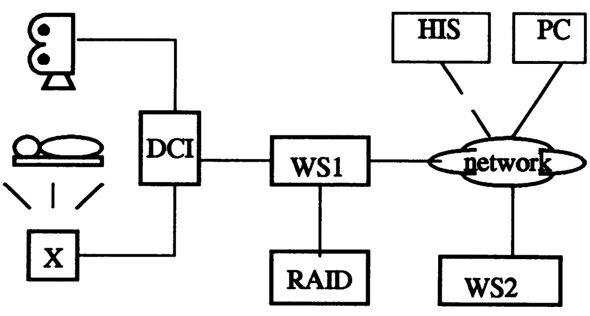

Figure 1. Hardware environment for MCAT prototype

The angiogram capture process runs on WS1 and monitors the DCI continuously. When the DCI starts to record angiograms, WS1 captures the data and stores them on local disks. The capturing system is described in detail in [4]. The captured video data is stored in a video data file in the format understood by MCAT.

Section 2 of this paper presents the functions of MCAT. Section 3 describes the design. Section 4 reports its implementation status, and Section 5 indicates the future directions.

MCAT FUNCTIONALITY

MCAT provides capabilities for annotating and clipping angiograms to form multimedia documents. It provides capabilities for doctors to exchange such documents via electronic mail, and examine them with personalized views. Figure 3 shows a typical MCAT screen.

MCAT can be used to build a multimedia document of a cath lab visit, which can become a component in the ECF. When a patient is selected, an angiogram viewing window and a list of runs (cardiac video acquisitions) of the patient will appear. The doctor can choose to view a run in either positive or inverted intensity mode. VCR-like buttons and the speed slider can be used to play the video in forward and reverse directions with various speeds, including single-frame stepping. The frame slider can be used to randomly jump to a particular frame in the run. Sliders are also provided to control brightness and contrast. When an abnormality is observed, the doctor can use the *pen* to draw marks (rectangles, circles or free-hand graphics) to attract the viewer's attention. The doctor can use the *voice* facility for dictation which can be later manually transcribed using the *text* facility. When the doctor finishes an annotation (dictating, drawing or text editing), the annotation will be automatically saved and attached to a selected sequence of the video. The VCR-like buttons and the frame slider can be used for frame sequence selection. The annotated angiograms can then be sent to the referring doctor using the *mail* facility. The document can also be archived as a component of the ECF.

Similarly, MCAT can be used to compose multimedia documents which can then be used by related tools for education and case presentation. A doctor can select key frames or key video sequences, annotate them, and compose them into a new document using the *copy, paste*, and *save as* options.

A doctor can use the angiogram viewing window to examine the angiograms in uni-plane or bi-plane mode. The doctor can replace the data in a particular viewing window at any time by the data of another patient. He/she can also use multiple viewing windows to compare side by side the angiograms of different patients or the angiograms of the same patient before and after therapeutic intervention.

In addition, each doctor can have multiple personalized views into the same multimedia angiogram. This is useful, for example, when the referring cardiologist has examined the document once and would like to see the video again without the annotations. In this case, the doctor can use the view editing facility to selectively turn on and off the annotations. A *view* is created automatically when a doctor views and annotates an angiogram. The views can be modified using the view editing facility and can be saved for later use upon user request.

MCAT DESIGN

Architecture

The MCAT architecture is designed with the following goals in mind. We will evaluate the design during the trial use and future development.

- Value-added but not intrusive: MCAT should be easily integrated into an existing patient record system. Some patient data, e.g. physiological and demographic data, are often captured by different systems and stored in different databases. MCAT should provide seamless access to the information with minimal changes.
- Scalable: MCAT should be able to handle computers with different capabilities and satisfy users with different requirements. Different doctors may use computers with different capabilities based on cost-capability considerations. For example, some review stations may not have audio capabilities and have only a low bandwidth link to networks. However, a hospital department may have a state-of-the-art workstation connected to a high bandwidth network. MCAT should be easily configured for various user needs and ported to systems with various capabilities.
- Good performance: MCAT should deliver the best video quality possible as required by the user and the system. Degradations in angiogram quality may cause difficulties in diagnosis and therefore impede acceptance of digital media in place of celluloid films. Processing and management of video, audio, text, and graphics should not create noticeable distortion, jitter or slowdown in the video.
- Easily extendible: It should be easy to add new functions to MCAT and to modify the existing ones. With increasing user experiences, we anticipate the needs to modify the existing functions and add new ones. It is therefore important to design MCAT for easy extendibility.

Figure 2 shows the MCAT architecture. The rectangles with dotted borders represent the ECF system to which MCAT interfaces. The rectangles with solid borders represent the MCAT software modules and the ovals represent objects. The filled ovals are files, and the unfilled ovals are

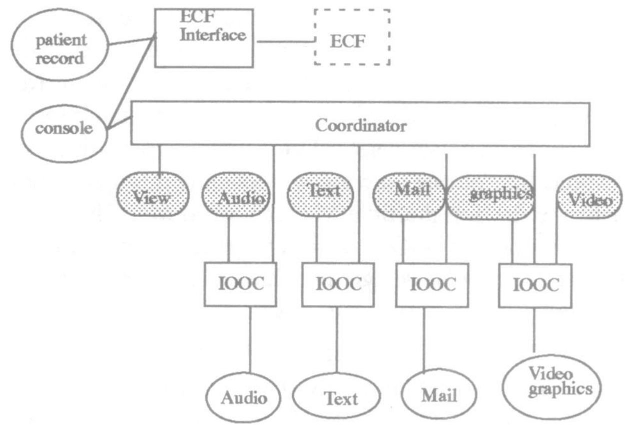

Figure 2. The MCAT Architecture

user interface objects. IOOC stands for I/O Object Controller.

In MCAT, the angiogram video and annotations are stored in separate data files. A data file can have a header and/or shadow file that keeps the information about the data. For example, a shadow file may record the type and the format of the data and the compress/decompress algorithms applied to the data. One or more *view* files indicate the relationship between the annotation data files and the angiogram frames. The use of shadow files and view files allows flexible manipulation of data and management of personalized views.

Video, audio, text, and graphic components are modeled as objects. For example, a run or a video clip is a video object, and each annotation is a separate object. Each object may interact with one or more user interface objects and data file objects. The data capturing devices, for instance, the audio devices (not shown in the figure) are also modeled as objects.

An I/O Object Controller (IOOC) is used to manage data capture and presentation of a particular object. For example, the video IOOC gets data from a video file generated by a capturing tool, process it if necessary, superimposes the video with the graphics if any, and displays it in the viewing window. The use of IOOCs facilitates easy adaptation to various end system features and capabilities. One or more IOOCs can be associated with an object, each of which adapts to a particular set of system capabilities and user requirements. For example, different IOOCs can be used for video on systems using different code/decode algorithms. The selection of IOOCs for a particular user can be determined by a resource file. IOOCs can also be selected to fit task needs. For example, one can specify in a resource file that only audio and text facilities are needed if the task is to transcribe doctor's dictation into text.

The *coordinator* gives instructions to the IOOCs to schedule and coordinate the presentation of video, audio, text, and graphics. The coordinator constructs the instructions according to interactive user input and the information stored in a user-selected view file. One coordinator is responsible for one viewing window and multiple coordinators exist for multiple viewing windows. The use of coordinator and IOOCs facilitate performance optimization. The modular design also makes it easier to add new functions and modify existing ones.

The *ECF Interface* integrates the MCAT into an existing HIS. While a patient record can be fetched by an ECF system, the MCAT-ECF interface selects the data related to the patient visit whose angiograms are to be reviewed. It transforms them into the format acceptable by MCAT, if necessary. It also transforms the data generated from MCAT to the format acceptable to the local ECF if appropriate.

GUI

The graphic user interface (GUI) of MCAT is designed with the following principles in mind. We will evaluate its effectiveness together with the doctors.

- Task oriented: MCAT is designed and organized for specific tasks performed by doctors at a cath lab instead of for general-purpose multimedia document authoring and presentation. Presentations of the tools are designed to be familiar to the doctors by mimicking the systems they currently use. For example, a click on the *voice* or *pen* simulates the *pick-up* of the tool and enables annotation, and second click simulates the *put-down* action and the annotation will be automatically saved and attached to the default or selected sequence of video frames.
- Minimal distraction: Studies have shown that human eyes tend to pay attention to changes and the use of fixed-appearance user interface increases productivity[5]. The MCAT GUI design tries to minimize screen changes by making the frequently used features for a task simple and keeping them on the screen. For example, the patient list and the run list (the simplest version of the view editing facility) are kept on the screen. Only when the user wants to edit a view, will the view editing window appear in full form.
- Eye-free controls: During the examination of angiograms, the doctor must focus full attention to the video. The key segments are often viewed repeatedly in forward and backward directions. Taking eyes away from the video to search for the GUI controls is unacceptable. For this reason, the MCAT supports video playing control using only the mouse over the video display.

PROTOTYPE IMPLEMENTATION

The MCAT prototype for Sun Sparc is currently under development at Philips Research Palo Alto. In anticipation of frequent changes in the user interface, we use Tcl/Tk [6] for GUI implementation. To ease the experimentation of object partitioning and integration, we use the scripting and tool communication capabilities of Tcl. The coordinator and IOOCs are implemented in C for efficiency purposes. Modules that require considerable inter-process communication (e.g. the video IOOC and the X server) are implemented as shared-memory processes to reduce data copying.

At the end of July, 95, we have completed the implementation of the audio tool and the video viewing tool with text and free-hand graphic annotation. Integration with the audio tool and ECF is in progress. Demonstrations are scheduled in September, 1995. Video clipping and view editing will be implemented in the next step.

FUTURE DIRECTIONS

After completion of the implementation, we plan to install MCAT in the Kaiser Hospitals at San Francisco and Oakland (CA) for trial use. In addition to improve the MCAT according to user feedback, we plan to improve and extend it in the following ways.

- Make MCAT a distributed application over heterogeneous networks, and research into the issues related to optimizations for performance and storage usages.
- Port MCAT to PCs and address the issues arising from heterogeneous end systems and networks.
- Add video conferencing capability to MCAT so that doctors can discuss a case while viewing and manipulating the same multimedia document.
- Examine the issues involved in incorporating MCAT into products such as EasyVision™, a multi-modality storing, viewing, scanning, and printing station, of Philips Medical Systems.
- Research into the issues of adding capabilities to view, annotate, and clip other modalities required for cath lab diagnosis, for example electrocardiograms, echocardiograms, and magnetic resonance images.
- Research into providing the capabilities for easy tailoring of user interface to fit a doctor's needs and personal taste.

CONCLUSION

We have presented a prototype of the Multimedia Cardiac Angiogram Tool (MCAT). It applies state-of-the-art computer technology to improve health care delivery at a cardiac cath lab. By providing seamless data collection

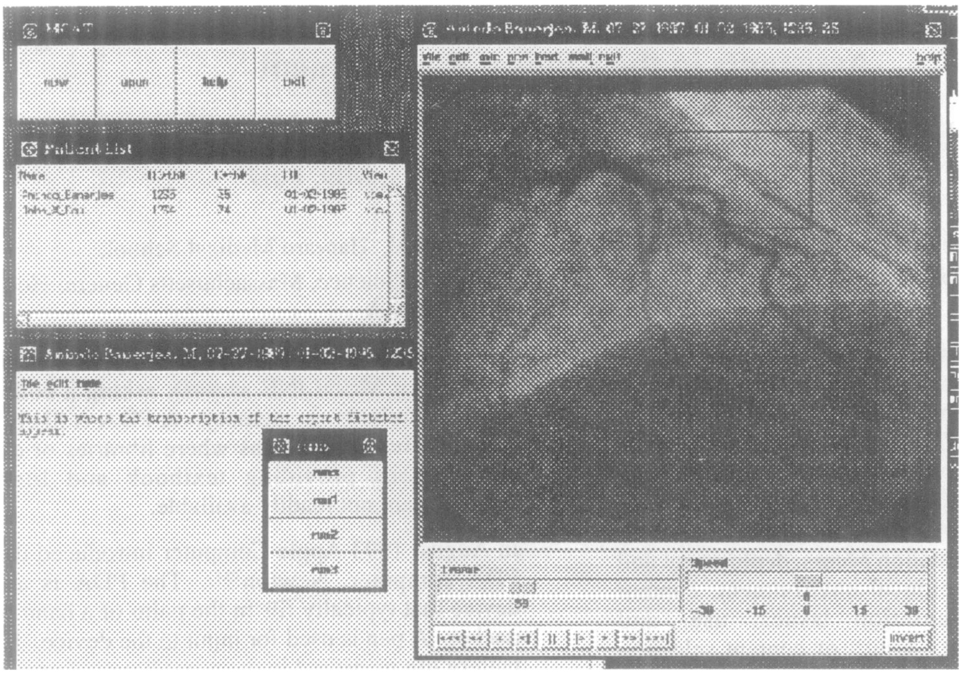

Figure 3. A typical screen of MCAT

from different systems, it can help reduce operating costs. By providing capabilities for multimedia angiogram annotation, mailing, and presentation, it can facilitate effective communication and collaboration between doctors and consequently improve patient care.

The interface to an ECF system is designed for easy integration into existing patient record systems. The design of the coordinator and the IOOCs makes it easy for MCAT to adapt to various system capabilities and user requirements, and facilitates system-specific performance optimizations. In addition, the modular design increases the extendibility of MCAT to new features and capabilities.

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